

ART. 9. THE PLEISTOCENE LOCAL FAUNA OF THE NATURAL CHIMNEYS, AUGUSTA COUNTY, VIRGINIA

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Introduction

Natural Chimneys, one mile north of the town of Mt. Solon, Augusta County, Virginia, is a well known tourist attraction in the west central part of the Great or Shenandoah Valley. Excavation of several small caves at its base proceeded at irregular intervals from 1949 through 1961 by Theodore B. Ruhoff and Carnegie Museum field parties. This collection comprises the Natural Chimneys local fauna, a late Wisconsin to early Recent sample of mammal, bird, reptile, amphibian, fish, snail and millipede remains.

Acknowledgments

Many people have been associated with this study and I wish to thank those who gave so generously of their time and talents. Mr. and Mrs. Gordon E. Brown, the owners of the site, have been extremely co-operative, assisting the field parties in every possible way. Theodore B. Ruhoff, now with the Smithsonian Institution, made the initial discovery of the bone site and during subsequent trips collected the bulk of the matrix from which the fauna was extracted. J. LeRoy Kay, Curator Emeritus of the Section of Vertebrate Paleontology, Carnegie Museum, made several trips to the site and was in charge of the earlier phases of the Museum's field operation. John A. Leppla, Field Associate, Carnegie Museum, spent many months washing matrix and picking out the hundreds of small jaws and teeth. His meticulous concern and scientific approach to the task is directly responsible for the recovery of most of the micro-fauna reported on herein.

Birds were identified by Alexander Wetmore, United States National Museum. The reptiles and amphibians were identified by Neil D. Richmond, Curator of Herpetology, Carnegie Museum. Walter Auffenberg, University of Florida, served as consultant. We wish to thank him for his identification of coachwhip and diamond-backed rattlesnake vertebrae. Gastropods were identified by Juan J. Parodiz, Curator of Invertebrates, Carnegie Museum, millipedes by Nell B. Causey, University of Arkansas. The red fox was checked by Caroline Heppenstall, Assistant Curator of Mammals, Carnegie Museum and by Charles O. Handley, Jr., Associate Curator of Mammals, United States National Museum.

I wish to thank Allen D. McCrady, Mr. and Mrs. Harold Hamilton, Ralph C. Bossart, W. Galen Barton and John A. Leppla for spot-checking details of deposition and geology at the site.

I am grateful to Neil D. Richmond, Harry B. Clench, J. Kenneth Douthett and Craig C. Black, for reading and criticizing portions of this manuscript.

The map was made by Mr. Bossart. Photographs by Neil D. Richmond (Fig. 1) and W. Galen Barton (Fig. 2 and 3). The drawing by Richard W. Lang (Fig. 4) was made possible by National Science Foundation grant, G-20868.

Special thanks are due my wife, Alice M. Guilday, for her invaluable assistance throughout every phase of the project.

Location

The Natural Chimneys are located one mile north of the town of Mt. Solon, Augusta County, Virginia, about fifteen miles west of Harrisonburg, Virginia. Geographical co-ordinates taken from the Parnassus Quadrangle, Virginia Geological Survey map are Lat. $30^{\circ} 22' N.$, Long. $70^{\circ} 5' W.$, Alt. 1357 feet above sea level.

The site is on the east bank of the wide flat valley of the North River, a tributary of the Shenandoah River system. At this point the Great Valley is 25 miles wide. Its floor lies at an elevation of 1350-1500 ft. Its western rim, Narrow Back Mountain, rises to 2300 ft., its eastern rim, Blue Mountain, to 2500 ft. at this spot. North River which drains the rugged mountain terrain west of the Great Valley enters it at North River Gap, four miles west of Natural Chimneys. Entering a flat valley fully a mile wide, the river turns abruptly north, flows parallel to Narrow Back Mountain for eight miles, then swings east to cross the floor of the Great Valley. Its fall is about 40 ft. per mile as it emerges from the gap. It is clear, cool and moderately swift.

Natural Chimneys lies at the base of a series of low (100 ft.) hills that lie on the floor of the Great Valley and form the east bank of the North River Valley. They face west across the wide expanse of the valley which continues flat for over a mile, rises 300 ft. in the next two miles, then precipitously some 700 ft. to the summit of Narrow Back Mountain some four miles west of the site.

Geology

The Natural Chimneys appear to be erosion remnants of a former fissure cave system. They (Fig. 1) are a group of chert-capped towers of upper Cambrian Elbrook dolomite. At this point in the valley the strata of the dolomite are horizontal. While the North River was flowing at a higher level than it does today, with a correspondingly higher regional water table, the "chimneys" appeared as a series of fissures and sink-holes open on the hilltop at the level of the highest "chimney." Subsequent deepening and lateral erosion of the North River Valley by stream meandering have exposed the dolomite pillars—the former walls between the open sink-holes. Subsequent erosion of the pillars themselves has reduced these former fissure walls to tall stone chimneys. The fortunate feature of a cap of insoluble chert has protected these pillars from destruction. The small caves at their base, Brown's Cave (Fig. 1, right) and the Cave of the Wooden Steps (Fig. 1, left) are probably remnants of former subterranean connections between sink-holes.

Deposition

The major portion of the bones was removed from the floor of Brown's Cave, although a few, including a mandible of *Microtus xanthognathus*, were found in wall cracks in the Cave of the Wooden Steps. In Brown's Cave (Fig. 2) the bone-bearing sector of the earth fill of the cave floor was concentrated about the mouth of the cave and extended back only a few feet. Secondary bone-bearing sites were scattered irregularly in side passages near the entrance. Some pockets of bone were discovered in cave earth on small ledges above the floor of the cave.

The top two feet of cave floor fill was a light coffee-brown when dry, deep red-brown when wet. It contained fragments of dolomite, speleothems, teeth, bone fragments and modern plant rootlets. It is important to note that all



Fig. 1. Natural Chimneys, Mount Solon, Virginia, looking north. Cave of the Wooden Steps, left. Brown's Cave, right



Fig. 2. Entrance to Brown's Cave, Natural Chimneys, Virginia. Note man standing inside the entrance, on fossiliferous matrix

of the rock fragments appeared to have been derived from the surrounding formation, that none was waterworn and that the deposit was not obviously stratified. The matrix was not water deposited but grew in place by decomposition of the surrounding cave walls and filling from above. Below two feet, the matrix turned redder and became sterile of bones and teeth. The dark color of the bone-bearing matrix is undoubtedly due to a higher organic content, possibly associated with owl roosts and wood-rat nests, neither of which occur there today.

The deposit of bone accumulated in several ways. Most important was the activity of owls. Owls, and other raptorial birds, regurgitate pellets of compacted bones, skulls and fur or feathers of small mammals or birds. Bones, lower jaws and partial skulls processed in this manner remain remarkably well preserved, and deposits containing many thousands of such items accumulate in a relatively few years about the roosts. The remains of at least 878 mammals were recovered from the matrix. Of these, 98 per cent. were rabbit-size or smaller. Approximately one-eighth of the entire fauna was shrews and an additional one-half of the total was small cricetid rodents. Mammals larger than a rabbit were represented only by scraps of bone or isolated teeth. This could not be attributed to post-depositional disturbance or water action as the good condition of many of the hundreds of smaller and more delicate bones proves. The presence of milk teeth or unerupted permanent teeth of wood-rats, porcupine, wolf, raccoon, deer, peccary and woodchuck may have meant that the cave was a former denning site at various times in the past. Large mammal bone fragments were invariably heavily gnawed by rodents, and possibly found their way into the cave as a result of the scavenging activities of a resident wood-rat population. The bones may have filtered down from former openings to surface sink-hole entrances in the present roof of the cave, or the present cave walls may have had a resident owl population. The high percentage of nocturnal flying-squirrels and low percentage of diurnal chipmunks are other good indications of owl activity. An owl roost deposit associated with the Sheep Rock Shelter, an archeological site in Huntingdon County, Pennsylvania (Guilday and Parmalee, ms.) had a similar preponderance of flying-squirrels, while at the New Paris #2 local fauna, Bedford County, Pennsylvania, where the victims simply tumbled into an open sink-hole, the proportion of flying-squirrel to chipmunk was ten to one hundred and nine (Guilday and Bender, 1958).

The bones and teeth, with exception of those of the larger mammals, are well preserved. They are a light ivory color and have not been mineralized. One or two are mottled, almost black, and appear to have been mineralized. The only specimens of this color that could be identified were some mandibles of the least shrew *Cryptotis*, the short-tailed shrew *Blarina*, and the pygmy shrew *Microsorex*. Brunner, 1959, working with similar faunas in Germany, has attempted to assign different ages to variously colored bones in chronologically mixed late Pleistocene deposits. This may not always be valid, however. While excavating the New Paris #4 fauna, Allen D. McCrady noted that black bone was almost invariably associated with air pockets and local discontinuities in the mud and rubble matrix. He attributed the coloration to organic action (bacterial ?) during the initial decomposition of the animal, or possibly to a chemical oxidation process. At this latter site all of the specimens, both ivory-white and black, were known to be of a common age.

Faunal List

Phylum Arthropoda

Class Diplopoda (identifications by Nell B. Causey)

Nannaria sp.

Phylum Mollusca (identifications by Juan J. Parodiz)

Class Archaeogastropoda

Hendersonia occulta

Class Mesogastropoda

*Pomatiopsis lapidaria**Valvata* sp.*Leptoxis* (*Mudalia*) *carinata*

Class Basommatophora

*Lymnaea catascopium**Physa heterostrophia*

Class Stylommatophora

*Triodopsis tridentata juxtidentis**Triodopsis* (*Neohelix*) *albolabris**Retinella electrina**Retinella virginica**Anguispira alternata angulata**Helicodiscus parallelus**Gastrocopta* (*Albinula*) *contracta*

Phylum Chordata

Class Osteichthyes

Cyprinidae, indeterminate, minnows

Catostomidae, indeterminate, suckers

Class Amphibia (identifications by Neil D. Richmond)

Diemictylus cf. *viridescens*, red-spotted newt*Ambystoma* sp., salamander*Desmognathus* sp., salamander*Scaphiopus* cf. *holbrooki*, spade-foot toad*Bufo* sp., toad*Hyla* sp., treefrog*Rana* cf. *catesbiana*, bullfrog*Rana palustris*, pickerel frog*Rana* sp., frog sp.

Class Reptilia (identifications by Neil D. Richmond)

Chelydra serpentina, snapping-turtle*Terrapene carolina*, box-turtle*Sceloporus* cf. *undulatus*, fence lizard*Natrix* sp., water-snake*Storeria* sp., red-bellied ? snake*Thamnophis* cf. *sirtalis*, garter-snake*Haldea* sp., earth snake*Diadophis* sp., ring-neck snake*Carphophis amoenus*, worm-snake*Coluber* cf. *constrictor*, black racer*Masticophis flagellum*, coachwhip snake*Opheodrys* sp., green-snake

Elaphe cf. *guttata*, corn-snake
Elaphe sp., rat-snake
Lampropeltis doliata triangulum, milk-snake
Lampropeltis sp.
Crotalus horridus, timber rattlesnake
Crotalus cf. *adamanteus*, diamond-back rattlesnake

Class Aves	Minimum number of individuals
(Identification and data from Alexander Wetmore)	
<i>Anas discors</i> , blue-winged teal	2
<i>Bucephala albeola</i> , bufflehead	1
<i>Oxyura jamaicensis</i> , ruddy duck	1
<i>Accipiter striatus</i> , sharp-shinned hawk	1
<i>Buteo jamaicensis</i> , red-tailed hawk	1
<i>Buteo lineatus</i> , red-shouldered hawk	1
<i>Buteo platypterus</i> , broad-winged hawk	1
<i>Canachites canadensis</i> , spruce grouse	1, or more
<i>Bonasa umbellus</i> , ruffed grouse	3, or more
<i>Pedioecetes phasianellus</i> , sharp-tailed grouse	4, or more
<i>Colinus virginianus</i> , bob-white	1
<i>Meleagris gallopavo</i> , turkey	2
<i>Grus americana</i> , whooping crane	1
<i>Charadrius vociferus</i> , killdeer	1
<i>Philohela minor</i> , woodcock	1, or 2
<i>Bartramia longicauda</i> , upland plover	1
<i>Catoptrophorus semipalmatus</i> , willet	1
<i>Erolia minutilla</i> , least sandpiper	1
<i>Ectopistes migratorius</i> , passenger-pigeon	21, or more
<i>Megaceryle alcyon</i> , belted kingfisher	1
<i>Colaptes auratus</i> , yellow-shafted flicker	1
<i>Centurus carolinus</i> , red-bellied woodpecker	1
<i>Melanerpes erythrocephalus</i> , red-headed woodpecker	2
<i>Dendrocopos pubescens</i> , downy woodpecker	1
<i>Sayornis phoebe</i> , eastern phoebe	3
<i>Contopus virens</i> , eastern wood pewee	1
<i>Petrochelidon pyrrhonota</i> , cliff swallow	8, or more
<i>Perisoreus canadensis</i> , gray jay	1
<i>Cyanocitta cristata</i> , blue jay	1
<i>Pica pica</i> , magpie	1
<i>Sitta canadensis</i> , red-breasted nuthatch	1
<i>Toxostoma rufum</i> , brown thrasher	1
<i>Turdus migratorius</i> , robin	1
<i>Hylocichla</i> sp., thrush (not identified to species)	1
<i>Agelaius phoeniceus</i> , red-winged blackbird	2
<i>Molothrus ater</i> , brown-headed cowbird	1, or more
<i>Junco</i> sp., junco (not identified to species)	1
<i>Zonotrichia albicollis</i> , white-throated sparrow	1
<i>Passerella iliaca</i> , fox sparrow	1
<i>Melospiza melodia</i> , song sparrow	1

Class Mammalia	Minimum number of individuals
Order Insectivora	
<i>Microsorex hoyi</i> , pygmy shrew	7
<i>Sorex</i> cf. <i>cinereus</i> , masked shrew	45
<i>Sorex fumeus</i> , smoky shrew	10
<i>Sorex arcticus</i> , arctic shrew	6
<i>Sorex palustris</i> , water shrew	4
<i>Cryptotis parva</i> , least shrew	5
<i>Blarina brevicauda</i> , short-tailed shrew	56
<i>Condylura cristata</i> , star-nosed mole	5
<i>Parascalops breweri</i> , hairy-tailed mole	3
<i>Scalopus aquaticus</i> , eastern mole	5
Order Chiroptera	
<i>Myotis keenii</i> , Keen's bat	39
<i>Myotis</i> cf. <i>lucifugus</i> , little brown bat	4
<i>Eptesicus</i> cf. <i>grandis</i> , pleistocene brown bat	2
<i>Eptesicus</i> cf. <i>fuscus</i> , big brown bat	1
<i>Eptesicus</i> sp.	12
<i>Pipistrellus subflavus</i> , pipistrelle bat	5
<i>Lasiurus</i> cf. <i>borealis</i> , red bat	1
Order Rodentia	
<i>Marmota monax</i> , woodchuck	2
<i>Citellus</i> cf. <i>tridecemlineatus</i> , thirteen-lined ground squirrel	2
<i>Tamias striatus</i> , chipmunk	6
<i>Glaucomys volans</i> , southern flying-squirrel	15
<i>Glaucomys sabrinus</i> , northern flying-squirrel	13
<i>Tamiasciurus</i> cf. <i>tenuidens</i> , pleistocene red squirrel	5
<i>Sciurus carolinensis</i> , gray squirrel	1
<i>Neotoma floridana</i> , wood-rat	37
<i>Peromyscus</i> cf. <i>maniculatus</i> , deer-mouse	35
<i>Peromyscus</i> cf. <i>leucopus</i> , white-footed mouse	12
<i>Peromyscus</i> sp. (<i>maniculatus</i> or <i>leucopus</i> ?)	83
<i>Synaptomys cooperi</i> , southern bog lemming	13
<i>Synaptomys borealis</i> , northern bog lemming	3
<i>Phenacomys</i> cf. <i>ungava</i> , spruce vole	10
<i>Clethrionomys gapperi</i> , red-backed vole	47
<i>Microtus xanthognathus</i> , yellow-cheeked vole	15
<i>Microtus chrotorrhinus</i> , rock vole	2
<i>Microtus pennsylvanicus</i> , meadow vole	40
<i>Microtus</i> cf. <i>pennsylvanicus</i> or <i>chrotorrhinus</i>	127
cf. <i>Pitymys pinetorum</i> , pine vole	65
<i>Ondatra zibethicus</i> , muskrat	6
<i>Napaeozapus insignis</i> , woodland jumping-mouse	9
<i>Zapus hudsonicus</i> , meadow jumping-mouse	13
<i>Erethizon dorsatum</i> , porcupine	2
<i>Castor canadensis</i> , beaver	1
<i>Castoroides ohioensis</i> , giant beaver	1

	Minimum number of individuals
Order Lagomorpha	
<i>Lepus americanus</i> , snowshoe hare	3
<i>Sylvilagus</i> sp., cottontail rabbit	1
Leporidae cf. <i>Lepus</i> or <i>Sylvilagus</i>	12
Order Carnivora	
<i>Canis</i> cf. <i>lupus</i> , wolf	1
<i>Vulpes</i> sp., red ? fox	1
<i>Ursus</i> cf. <i>americanus</i> , black bear	1
<i>Lynx</i> ?, indeterminate small cat	1
<i>Procyon lotor</i> , raccoon	1
<i>Martes americana</i> , pine-marten	1
<i>Martes</i> cf. <i>pennanti</i> , fisher	1
<i>Mustela vison</i> , mink	2
<i>Mustela</i> cf. <i>frenata</i> , long-tailed weasel	3
<i>Mustela</i> cf. <i>rixosa</i> , least weasel	1
<i>Mephitis mephitis</i> , striped skunk	1
Order Artiodactyla	
<i>Mylohyus</i> sp., long-nosed peccary	1
<i>Odocoileus virginianus</i> , white-tailed deer	2
Cervidae ?, indeterminate large artiodactyl	1

Discussion of Fauna

The bird bones recovered from Natural Chimneys are at the United States National Museum, Washington, D.C. (U.S.N.M.). The remainder of the collection is in the Section of Vertebrate Fossils, Carnegie Museum, Pittsburgh, Pa. (C.M.)

Invertebrates (See Faunal List)

Remains of one calcified millipede *Nannaria* sp. and 13 species of snails, both terrestrial and aquatic, were recovered. No pelecypod remains were recovered strengthening the assumption that the bone-bearing matrix was of terrestrial origin.

Fish (See Faunal List)

Fish remains were common in the matrix. Without exception, however, they constituted fish of "minnow size," the largest perhaps 12" long, the majority less than half of that. Kingfishers, mink, or other terrestrial fish predators may have been responsible for these remains or occasional high waters may have flooded the site allowing schools of small fish to die in the cave as the water receded. If such was the case, however, the flooding was of a benign and temporary nature that disturbed the deposit very little if at all.

Amphibians (See Faunal List)

Material: C.M. 7605 through 7612.

Reptiles (See Faunal List)

Material: C.M. 7589 through 7604, 7614.

Remarks: The coachwhip, *Masticophis flagellum*, 1 vertebra, C.M. 7596 and the diamond-backed rattlesnake, *Crotalus adamanteus*, 1 vertebra, C.M. 7614, are of southern affinities. Neither species is found in Virginia today but approach its southern border. These two species are the only forms in the Natural Chimneys local fauna whose range does not extend as far north as

the site today. Is this an indication that ranges of ectothermal animals will respond more rapidly to temperature change than will those of endothermal animals? Perhaps the temperature rise associated with the post-Wisconsin "Climatic Optimum" was enough to enable these snakes to range farther north than they do today, while endothermal species remained relatively unaffected? This is pure speculation, however. There is no way of knowing whether these snakes were contemporary with the boreal fauna (which seems extremely doubtful), or whether they preceded or followed it in time.

Birds

By Dr. Alexander Wetmore, United States National Museum

In the list of birds, the spruce grouse and the gray jay are species of boreal range that today live in northern coniferous forests. The sharp-tailed grouse, northern and northwestern in modern distribution, has been found recently in late Pleistocene deposits of New Paris #4 sink-hole in Pennsylvania (Wetmore, 1959), so that its occurrence at Natural Chimneys represents a point to the southward in its ancient range. The magpie is definitely western and northern, here recorded for the first time in eastern United States under conditions of natural distribution. The abundance of remains of the passenger-pigeon, now extinct, is interesting, as is a fragment from the skeleton of the whooping crane, formerly common, but for which there are few records in the eastern United States. The remaining species on the list in modern times range widely to the north, and also are found as residents or as migrants in Virginia, so that there is nothing unusual in their presence in this Natural Chimneys fauna at the end of Wisconsin time.

Mammals

Order: INSECTIVORA

Family: Soricidae

The collection is exceptionally rich in shrews. It contains at least 230 lower jaws and 28 partial skulls representing 136 animals belonging to seven species (See Fig. 3). The high number of shrews can be attributed to owl predation. Identification to species was based entirely upon dental and cranial characters. Fortunately most of the mandibles were in excellent condition and characters of specific value were present. The following two keys present characters which will differentiate the mandibles of the soricids of eastern North America. Those marked with an asterisk are present in the Natural Chimneys local fauna.

Key to the Genera of Eastern North American Soricidae Based on Mandibles

A. Size small (ramus length, 6.5 mm.). Entoconid of molars greatly reduced.

*Microsorex**

B. Size large (ramus length, 7 mm. or more). Entoconid of molars well developed.

1. Talonid of M_3 reduced.

*Cryptotis**

2. Talonid of M_3 not reduced.

a. Articular facets of condyle separated by concave area. Angular process short, stocky. Mandible heavy and massive.

*Blarina**

- b. No concave area between articular facets of condyle. Angular process long and delicate. Mandible light and delicate.

*Sorex**

Key to the Genus *Sorex* in Eastern North America Based on Mandibles

The following key to the mandibles of eastern *Sorex* should be used in conjunction with adequate comparative material. It is intended as a working guide only. All measurements were taken with an ocular micrometer under 10× magnification.

- A. Post-mandibular foramen present and well developed.

*Sorex arcticus**

- B. Post-mandibular foramen absent or weakly-developed (See 2a).

1. Valley separating protoconid and hypoconid of M_1 *deep*, extending to external cingulum. (Also true of *S. arcticus*.) Size large, condyle width over 2 mm.

*Sorex palustris**

2. Valley separating protoconid and hypoconid of M_1 *shallow*, extending almost, but not quite to external cingulum.

- a. Size medium, condyle width 2 mm. Post-mandibular foramen present in 20% of cases (5 out of 25 Pennsylvania specimens), but always small and close to mandibular foramen.

*Sorex fumeus**

(In actual practice, *S. fumeus* can be most readily confused with *S. arcticus*, but the following characters separate the two: depth of the proto-hypoconid valley of M_1 , the post-mandibular foramen; the dentary of *S. arcticus* is heavier and the lower incisor is stouter, yet the first molar is slightly smaller than in *S. fumeus*.)

- b. Size small—condyle width 1.5 mm.

- aa. Dentary delicate and elongated, length over 8 mm.

Sorex dispar

(*S. gaspensis* was not examined, but its affinities appear to lie with *S. dispar*.)

- bb. Dentary short and relatively stocky, length 7.5 mm.

*Sorex cinereus**

Sorex longirostris

Sorex cf. *cinereus* Kerr—Masked Shrew

Material: C.M. 7551, 7552. 72 whole or partial mandibles. 3 left and 2 right partial maxillae.

Distribution: Northern North America south to Pennsylvania, thence south in the Appalachian Mountains to Georgia.

Habitat: Cool, damp terrain with a heavy ground cover in both forested and open situations.

Remarks: *Sorex longirostris* occurs or may be expected to occur at the site today (Bruce, 1937). Apart from a slightly smaller average size, its mandible is indistinguishable from that of *S. cinereus*. Both species may conceivably have been represented in the deposit. The specimens were referred to *S. cinereus* because they averaged slightly

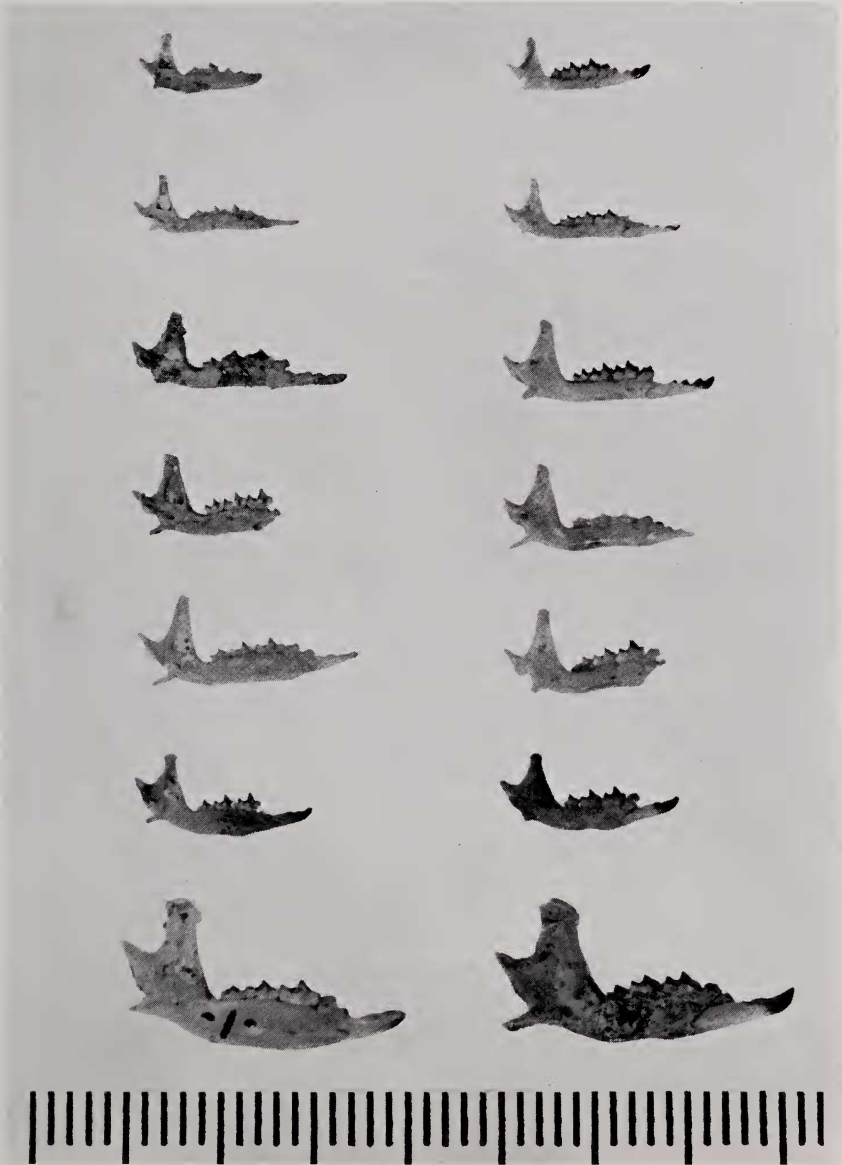


Fig. 3. Lower jaws of shrews from the Natural Chimneys local fauna
Scale in mm.

Top to bottom:	<i>Microsorex hoyi</i>	C.M. 7554a	C.M. 7554b
	<i>Sorex cf. cinereus</i>	C.M. 7551a	C.M. 7552a
	<i>Sorex fumeus</i>	C.M. 7550a	C.M. 7550b
	<i>Sorex arcticus</i>	C.M. 7549a	C.M. 7549b
	<i>Sorex palustris</i>	C.M. 7548a	C.M. 7548b
	<i>Cryptotis parva</i>	C.M. 7553a	C.M. 7553b
	<i>Blarina brevicauda</i>	C.M. 7545a	C.M. 7545b

larger than the *S. longirostris* used for comparative material. *S. longirostris* is a shrew of the southeastern United States reaching its northern limits on the Atlantic drainage in Maryland. If it is present in the deposit it was not a member of the late Pleistocene, boreal component of the fauna.

Sorex cinereus is primarily an animal of the higher mountain elevations in the state today.

Sorex fumeus Miller—Smoky Shrew

Material: C.M. 7550. 18 mandibles, 2 partial right maxillae.

Distribution: Appalachian Mountains from Georgia north to New Brunswick, west to northern shore of Lake Superior.

Habitat: Moist, cool forest with abundant ground cover, but found in a variety of situations such as bogs and mountain meadows.

Remarks: This is a mountain mammal in Virginia today, occurring at altitudes exceeding 2000 ft. and would not be expected to occur at the site, although it is undoubtedly present on the slopes of North Mountain, five miles west and 1000 ft. higher than Natural Chimneys.

Sorex arcticus Kerr—Arctic Shrew

Material: C.M. 7549. 15 mandibles, 3 partial skulls, 1 palate.

Distribution: Canadian life zone, south to Wisconsin and New Brunswick.

Habitat: Boreal bogs, damp meadowlands in coniferous forests.

Remarks: This is the first record of the arctic shrew from the Pleistocene of the eastern United States although it is known from Illinoian deposits of the Doby Springs local fauna in Oklahoma (Stevens, 1960). Its present southern limit in the Appalachian area is New Brunswick. Fortunately, the specific characters of the skull and mandible are so pronounced that its presence in any cave fauna would not go unrecognized, provided adequate material was preserved.

Sorex palustris Richardson—Water Shrew

Material: C.M. 7548. 7 mandibles, 1 partial skull, 1 rostrum, 1 maxilla.

Distribution: Canadian life zone of North America, south along the crests of the Appalachian Mountains to Tennessee.

Habitat: Along the banks of streams or mountain lakes.

Remarks: Not previously recorded from the state, this shrew may possibly be found living in the higher mountain bogs above 3000 ft.

Microsorex hoyi (Baird)—Pygmy Shrew

Material: C.M. 7554. 1 partial skull, 12 mandibles.

Distribution: Canadian and transition zones of North America, south to the Piedmont of Virginia.

Remarks: Judging from the size of collections, this nominally boreal shrew is one of the rarest of eastern North American mammals. It has only been taken twice in Virginia (Handley and Patton, 1947, p. 109). There is, apparently, only one known modern Pennsylvania specimen, recovered from a fox stomach (Roslund, 1951, p. 40). The pygmy shrew is also known from the New Paris #4 local fauna. Bedford County, Pennsylvania (Guilday and Bender, 1960).

Blarina brevicauda (Say)—Short-tailed Shrew

Material: C.M. 7544-7547. 100 mandibles, 4 partial skulls, 11 maxillae.

Distribution: Central and eastern North America north to the Hudsonian life zone.

Habitat: In a variety of terrestrial habitats wet and dry, from grasslands to dense forest.

Remarks: The short-tailed shrew, the commonest soricid in the deposit, is also the commonest shrew in Virginia today. The average size of the mandibles and teeth in the collection is larger than comparable modern material from Pennsylvania. Some specimens are distinctly larger and more rugged than any modern *B. brevicauda kirtlandi*, and compare favorably with the large late Pleistocene *B. brevicauda* from the New Paris #4 local fauna, Pennsylvania.

Cryptotis parva (Say)—Least Shrew

Material: C.M. 7553. 1 partial skull, 7 mandibles.

Distribution: Central and eastern United States, north to central New York.

Habitat: Grasslands, prairies.

Remarks: The least shrew, in contrast to the other soricids from the deposit, is a field form of southern affinities. It may possibly have postdated the late Pleistocene fauna and is a common mammal in the state today.

Family: Talpidae

Parascalops breweri (Bachman)—Hairy-tailed Mole

Material: C.M. 7540. 3 mandibles, 5 humeri, 2 upper molars.

Distribution: Appalachian Mountains of eastern United States from Tennessee north to Maine, west to north shore of Lake Superior.

Habitat: Well-drained soils irrespective of surface cover, avoids wet situations.

Remarks: The hairy-tailed mole is confined to the mountainous areas of western Virginia today at altitudes of 3000 ft. or more. This mole and *Scalopus aquaticus* do not occupy common ground in Virginia today. Their remains were both present in this deposit but may not have been contemporaneous.

Scalopus aquaticus (Linnaeus)—Eastern Mole

Material: C.M. 7542. 10 mandibles, 5 humeri, 4 partial skulls.

Distribution: Central and eastern United States, north to Michigan and Massachusetts, avoiding the Appalachian Mountain and Plateau region. (See Guilday, 1961, for exception to this.)

Habitat: Well-drained alluvial soils.

Remarks: The common mole at the site today.

Condylura cristata (Linnaeus)—Star-nosed Mole

Material: C.M. 7541. 5 mandibles, 8 humeri.

Distribution: Eastern North America from James Bay and southern Labrador south to Georgia.

Habitat: Wet meadows, bogs, in both coniferous and deciduous forest.

Remarks: Commonest in the mountainous sections of western Virginia today.

Order: CHIROPTERA

Family: Vespertilionidae

Myotis keenii (Merriam)—Keen's Bat

Material: C.M. 7566, 7567. 10 left, 9 right maxillae, 3 partial skulls.

C.M. 7568. 39 right, 21 left mandibles are referred to this species.

Distribution: Newfoundland to southern Alaska, south to Florida.

Remarks: *Myotis grisescens* Howell has recently been reported from fragmentary material found in three West Virginia caves and the Cumberland Cave, Maryland (Handley, 1956, p. 251). Upper dentitions of *M. keenii* are readily distinguishable from those of *M. grisescens*. Lower dentitions, apart from a slightly greater average size, are hard to separate with any degree of confidence. None of the upper dentitions from Natural Chimneys was *M. grisescens*. C.M. 7566, a right maxilla containing C-M³ plus the alveoli of the first two incisors has only two premolars rather than the normal three. It was originally identified as *Plecotus* sp. Closer study indicated that it was an abnormal *M. keenii* with a congenitally missing premolar. This condition is not too rare in the genus (Frum, 1946).

Myotis keenii is not as common in Appalachian caves today as is *M. lucifugus*, the proportion being about 10 *M. lucifugus* to 1 *M. keenii*. It was apparently the commonest bat at Natural Chimneys. It was also the commonest species of bat encountered at the late Pleistocene New Paris #4 local fauna in Pennsylvania (98 *M. keenii*, 54 *M. cf. lucifugus* recovered to date). Could it be possible that *M. keenii* was a more successful species under the boreal conditions of late Pleistocene times in the Appalachians? Perhaps it is significant to note that the young are "probably born later than those of most other bats in the United States". (Hall and Kelson, 1959, p. 167.) Would this adaptation enable it to establish itself as a breeding species in higher latitudes or in harsher climates more successfully than other members of the genus?

Myotis, species ?

Material: C.M. 7569. 1 right, 1 left maxilla. C.M. 7570. 4 right, 1 left mandible. C.M. 7571. 1 right mandible.

Remarks: C.M. 7569 and C.M. 7570 are presumably either *M. lucifugus*, *M. sodalis* or *M. austroriparius*. *M. lucifugus* is the common little brown bat in the area today. *M. austroriparius* is a southern species that has not been taken in Virginia. It would hardly be expected to occur in a deposit containing so many boreal mammals.

C.M. 7571, a right mandible with full dentition broken at the ascending ramus is from an extremely large *Myotis* (C-M₃ is 6.8 mm.). It appears to be larger than either *M. keenii* or *M. grisescens*. In all characters except the depth of the *symphysis mandibuli* and the large canine and premolars it agrees with *M. keenii*. The cingulum of the molars appears lighter than *M. grisescens*. It may be an unusually large *M. keenii*. At some future date, when the bat fauna of the Appalachian Pleistocene is better known, this specimen should be re-examined.

Pipistrellus cf. subflavus (F. Cuvier)—Pipistrelle

Material: C.M. 7572. 1 partial skull, 2 left maxillae, 5 left, 2 right mandibles.
 Distribution: North America, east of the Great Plains, south to Honduras,
 north to southern Quebec.

Remarks: Common at the site today.

Eptesicus cf. grandis (Brown)—Pleistocene Big Brown Bat

Material: C.M. 7563. 1 right, 1 left maxilla, 2 right, 2 left mandibles.
 Remarks: See below under *Eptesicus cf. grandis* or *fuscus*.

Eptesicus cf. fuscus (Palisot de Beauvois)—Big Brown Bat

Material: C.M. 7562. 1 palate, 1 left mandible.
 Remarks: See below under *Eptesicus cf. grandis* or *fuscus*.

Eptesicus cf. grandis or *fuscus*

Material: C.M. 7564. 1 palate, 1 right, 1 left maxilla, 12 left, 8 right mandibles, all fragmentary. 1 humerus, 1 occipital with partial right zygomatic arch.

Remarks: It is unfortunate that the *Eptesicus* remains from this site are so meager and fragmentary, as they appear to demonstrate intergradation between the large Pleistocene *E. grandis*, (or *E. fuscus grandis*) and the smaller, modern *E. fuscus fuscus*. What appear to be typical examples of both forms (See above) are represented in the collection. Brown, the describer of *grandis*, considered it a subspecies of *E. fuscus*, "probably the direct ancestor of the living *V. fuscus*." (Brown, 1908, p. 175). Gidley and Gazin, 1938, referred the big brown bats of Cumberland Cave, Maryland, to *Eptesicus grandis* and were of the opinion that it was a full species. A single mandible of this form has been recovered from the New Paris #4 local fauna, Pennsylvania, and Handley, 1956, records a mandible from Windy Mouth Cave, Greenbrier, County, W. Va. Unfortunately there is no guarantee that the collection represents a temporal unit population. Perhaps the *grandis* remains predated the *fuscus* material. The final taxonomic interpretation of this collection and the status of the form *grandis* had best be deferred until such time as more Pleistocene faunas are available.

Lasiurus borealis (Muller)—Red Bat

Material: C.M. 7565. 1 partial skull.
 Distribution: Southern Canada to Central America, exclusive of the Great Plains and the Rocky Mountains.
 Remarks: Although ordinarily considered a tree bat rather than a cave form, remains of red bats are quite often found in cave sites. Common in the area today.

Order: RODENTIA

Family: Sciuridae

Marmota monax Linnaeus—Woodchuck

Material: C.M. 7530. 2 left mandibles, 1 left maxilla, 18 isolated teeth.
 Distribution: From Alabama to Labrador, west to Alaska.
 Habitat: Found in varied situations, from dense forest to open meadowlands. Prefers well-drained situations for burrow.
 Remarks: Common in the area at the present time.

Citellus cf. *tridecemlineatus* (Mitchell)—Thirteen-lined Ground-Squirrel

Material: C.M. 7535. 2 left, 1 right maxillae, 12 molars, 2 partial mandibles.

Distribution: Central Great Plains and upper Mississippi River Valley, from Ohio west to Utah and from Texas to central Alberta and Saskatchewan.

Remarks: The specimens from Natural Chimneys indicate a squirrel slightly more robust than the living form. (Based upon specimens from a feral population in northwestern Pennsylvania in the collections of Carnegie Museum.) This is the first record of the former occurrence of the thirteen-lined ground-squirrel in Virginia. It was reported from the Cumberland Cave local fauna, Maryland (Gidley and Gazin, 1938), and is present in the New Paris #4 local fauna of Pennsylvania. All three localities are well east of its present range. This is a prairie form that avoids the eastern forests entirely and stops at the western margin of the Appalachian Plateau in central Ohio. A feral colony near Polk, Pennsylvania, introduced into a grassland area over 50 years ago, is thriving, but appears limited by wooded conditions; so, apparently, the animal is capable of surviving in eastern areas, provided proper grasslands are available.

Tamias striatus (Linnaeus)—Chipmunk

Material: C.M. 7558-7560. 6 left and 8 right whole or partial mandibles. 6 left, 4 right maxillae.

Distribution: Eastern North America, from James Bay to Georgia and the central Mississippi Valley north to Lake Winnipeg.

Habitat: Forest or forest-edge situations throughout the eastern deciduous forests. Avoids grassland as a rule but is extremely adaptable.

Remarks: Common in the area today. All of the specimens were fragmentary. There appears to have been two size classes present; the smaller comparable to modern Pennsylvania material (C.M. 7558). These may represent the extremes of a single population or, more likely, the sample consists of late Pleistocene and Recent individuals mixed. Their final interpretation lies in a comprehensive study of variation in *T. striatus* that is outside the scope of this paper.

Sciurus carolinensis Gmelin—Gray Squirrel

Material: C.M. 7536. 1 fragmentary maxilla with alveoli of P³-M².

Distribution: Eastern deciduous forests, Florida to southern Ontario.

Habitat: Forest or forest-edge situations of mast or nut-producing trees.

Remarks: Both the gray squirrel and the fox squirrel (*Sciurus niger*) are present today in Virginia but the preserved material was so fragmentary that only this one fragment bearing the alveolus for the characteristic P³ was specifically identifiable.

Sciurus, species ?

Material: C.M. 7537. 1 right frontal, 1 mandible fragment, 15 isolated molars.

Tamiasciurus cf. *tenuidens* (Hay)—Pleistocene Red Squirrel

Material: C.M. 7533. 5 left, 2 right partial mandibles, 2 maxillae, 1 humerus.

Distribution: Extinct. Known from three other Appalachian Pleistocene sites,

Cavetown, Maryland (Hay, 1920), Cumberland Cave, Maryland (Gidley and Gazin, 1938), and New Paris #4, Pennsylvania.

Habitat: Unknown, presumably arboreal, associated with a pollen flora indicating boreal, coniferous parkland at New Paris #4, Pennsylvania (Guilday and Bender, 1960).

Remarks: Distinguishable from modern *Tamiasciurus hudsonicus* (Erxleben) by superior size, more robust appearance, relatively deeper mandible, and greater depth of lower incisor. Compared with referred material from New Paris #4, Pennsylvania in the collection of Carnegie Museum, they showed no differences.

Tamiasciurus, species ?

Material: C.M. 7534. 4 left fragmentary mandibles, 4 fragmentary maxillae, 2 femora.

Remarks: *Tamiasciurus hudsonicus* (Erxleben) is the only species of this genus in the area today. It may possibly be represented in the collection, but the material is too fragmentary to tell.

Glaucomys volans (Linnaeus)—Southern Flying-Squirrel

Material: C.M. 7532. 11 left, 15 right mandibles, 8 maxillae, 4 humeri, 2 femora, 2 radii, 1 frontal.

Distribution: Eastern North America, from Florida to southern Ontario, plus a relict distribution in the mountains of Mexico and Central America.

Habitat: Inhabits a wide variety of forest situations at all altitudes, but does not thrive in Canadian zone situations.

Remarks: This is the only flying-squirrel at the site today. It and the northern flying-squirrel were represented by a minimum of 28 individuals out of a total sciurid collection of at least 50 animals representing 7 species. This is unquestionably due to the hunting activities of the owls that are believed primarily responsible for the bone deposit.

Glaucomys sabrinus (Shaw)—Northern Flying-Squirrel

Material: C.M. 7531. 13 left, 7 right mandibles, 17 maxillae, 5 humeri, 3 femora, 3 frontals, 1 scapula, 1 radius.

Distribution: Hudsonian and Canadian life zone, from Alaska to Labrador, south to Wisconsin and Pennsylvania, plus a relict distribution down the Appalachian Mountains at altitudes exceeding three thousand feet.

Habitat: Forest situation, coniferous or mixed coniferous-deciduous.

Remarks: Specimens are larger and more robust than modern Pennsylvania comparative material. The measurements fall within the range of more northerly modern races (Howell, 1918).

The two flying-squirrels from the deposit are readily separated by size. Modern Pennsylvania examples of *G. s. macrotus* and *G. v. volans* will occasionally overlap in certain cranial measurements (length of lower toothrow, for instance), but the two Natural Chimneys populations did not do so due to the relatively greater size of the *G. sabrinus* from the deposit.

Length of lower tooththrow (P_4-M_3), *Glaucomys*, Natural Chimneys

mm.	6.0	1.1	2.3	4.5	6.7	8.9	10.1	12.3	4.5	6.7	8.9	8.0	1.2	3.4	5		
<i>G. volans</i>			1	7	2	3	2	1	1								
<i>G. sabrinus</i>									1	1	7	1	2		1	3	1

Glaucomys sabrinus has not heretofore been reported from Virginia, although it may yet be taken on some of the higher mountain peaks. Its presence at the site can only be indicative of former climatic change in the area.

A fragmentary mandible from Cumberland Cave, Maryland identified as *Glaucomys* sp., is described as being "about the size of *G. sabrinus*" (Gidley and Gazin, 1938, p. 56). This is the only species of flying-squirrel present in the New Paris #4 local fauna, Pennsylvania. Interestingly enough, the Recent fauna from the New Paris #2 local fauna produced only *Glaucomys volans* (Guilday and Bender, 1958). The species do occur together in some portions of their range today, however, so they could have co-existed at Natural Chimneys.

Family: Castoridae

Castor canadensis Kuhl—Beaver

Material: C.M. 7539. 1 lower incisor, 1 upper molar.

Distribution: Continent-wide.

Habitat: River and stream courses, permanent bodies of fresh water.

Remarks: Re-established in Virginia today.

Castoroides ohioensis Foster—Giant Beaver

Material: C.M. 7538. 1 upper molar.

Distribution: Extinct. Known from many Pleistocene sites throughout the continent, from Alaska south to Oregon, and east to Texas, South Carolina, and New York (Cahn, 1936).

Habitat: Possibly cattail swamps and lakes. Does not appear to have been adapted for tree-felling (Powell, 1948).

Remarks: This appears to be the first Virginia record of the giant beaver.

Family: Cricetidae

Subfamily: Cricetinae

Peromyscus cf. *maniculatus* (Wagner)—Deer-Mouse

Material: C.M. 7508, 7509, 7513. 1 partial skull, 35 left, 32 right mandibles.

Distribution: Most of North America south of the tree line. Avoids the Atlantic coastal plain and the southeastern United States except in the mountains.

Habitat: One subspecies or another occupies almost every terrestrial habitat available within its range.

Remarks: A form larger than *P. m. bairdi*, about the size of modern *P. m. nubiterrae*, is indicated by the dentitions. *P. m. nubiterrae* is the only form of this mouse known from the state. It is restricted to the mountains, in moist woods above 2500 ft. (Handley and Patton, 1947), and does not occur at the Natural Chimneys today. It is not possible to identify the Natural Chimneys specimens to subspecies, but the presumption is that it is most probably a cool

forest race. This would be in harmony with the boreal element of the fauna.

Peromyscus cf. *leucopus* (Rafinesque)—White-footed Mouse

Material: C.M. 7510. 12 left, 7 right mandibles.

Distribution: Temperate North America, east of the Rocky Mountains, south of the Hudsonian life zone. Avoids the southeastern lowlands.

Habitat: Wooded or brushy areas at all elevations.

Remarks: *Peromyscus leucopus* is the only species of deer-mouse at the site today. See remarks under *Peromyscus* sp. below.

Peromyscus, species ?

Material: C.M. 7511, 7512. 94 maxillae, 83 left, 64 right mandibles.

Remarks: Probably *P. maniculatus* or *leucopus* or both. Only unworn first molars were considered diagnostic enough to warrant specific identification. *Peromyscus gossypinus* (LeConte) and *Peromyscus nuttalli* (Harlan) reach the northern limits of their distribution in the state, but neither occurs in Augusta County today, nor do they appear to have been represented in the Natural Chimneys local fauna.

Neotoma floridana (Ord)—Wood-rat

Material: C.M. 7527. Maxillae, mandibles, isolated molars, fragmentary skeletal elements of at least 37 individuals.

Distribution: Southern half of the United States from New Mexico to the Atlantic Coast, north to the Dakotas, Illinois and southern Connecticut.

Habitat: Restricted in the Appalachians to rocky outcrops in forested country at higher elevations.

Remarks: In contrast to the *Neotoma* from the Cumberland Cave local fauna, Maryland (Gidley and Gazin, 1938) and the New Paris #4 local fauna, Pennsylvania, which appears to be larger than the modern *N. f. magister*, the specimens from Natural Chimneys agree in every respect with specimens of *N. f. magister* from Huntingdon County, Pennsylvania. These rats have an affinity for cliff, talus and cave situations and probably lived in the shallow cave. Their habit of accumulating all manner of objects in their living quarters may have been responsible for some of the larger mammal fragments in the deposit, many of which were badly gnawed.

Subfamily: Microtinae

Synaptomys cooperi Baird—Southern Bog Lemming

Material: C.M. 7504. 5 left, 13 right mandibles or isolated M₁s, or both.

Distribution: Northcentral and northeastern United States, south to Arkansas and North Carolina, and southeastern Canada.

Habitat: A variety of grassland situations from sphagnum bog to dry upland clearings in forest or prairie situations.

Remarks: The southern bog lemming is known from two other cave deposits in the Appalachian Mountains: Frankstown Cave, Pennsylvania (Peterson, 1926) and New Paris #4, Pennsylvania (Guilday and Bender, 1960). It has been reported from as far south as San Josecito Cave, Nuevo Leon, Mexico (Jakway, 1958).

Synaptomys borealis (Richardson)—Northern Bog Lemming

Material: C.M. 7502. 3 left, 3 right mandibles.

Distribution: Hudsonian life zone from Alaska to Labrador, south to northern Minnesota and the White Mountains of New Hampshire.

Habitat: Varied; dry, grass-grown, second growth spruce and poplar, thick gloomy spruce woods carpeted with sphagnum, grass clumped willow swamp (Soper, 1942), small meadow, wet swamp, moist spruce woods (Soper, 1948).

Remarks: This is the first state record for the northern bog lemming. Lemmings of the subgenus *Mictomys* are also known from the Cumberland Cave, Maryland (Gidley and Gazin, 1938), New Paris #4, Pennsylvania (Guilday and Bender, 1960), and the Cudahy Fauna of Kansas (Paulson, 1961).

Synaptomys, species . . . *cooperi* or *borealis*

Material: C.M. 7503. 3 partial palates.

Clethrionomys gapperi (Vigors)—Red-backed Vole

Material: C.M. 7517-7519. 18 maxillae, 47 left, 46 right whole or partial mandibles.

Distribution: Hudsonian, Canadian, and Transition life zones from Alaska to Labrador, south in the Appalachian Mountains to North Carolina.

Habitat: Among rocks, under logs, in subsurface burrows in cool, damp forest situations.

Remarks: Although this is one of the commonest small mammals in the collection it does not occur at the site today. In Virginia it is restricted at the present time to areas of cool, moist forest in the mountain ridges but does not reach the floor of the Great Valley. Its presence at the site indicates climatic change. Remains of red-backed mice are known from two other Appalachian cave faunas, Frankstown Cave, Pennsylvania (Peterson, 1926) and New Paris #4, Pennsylvania (Guilday and Bender, 1960).

Phenacomys cf. *ungava* Merriam—Spruce Vole

Material: C.M. 7501. 9 left, 10 right mandibles or M_1 s, or both.

Distribution: Hudsonian and Canadian life zones of Canada, south to northern Minnesota and northern shore of the Gulf of St. Lawrence.

Habitat: Dry, well-drained sites in pine and spruce boreal forest preferred, but in periods of great abundance found in a wide variety of boreal forest habitats (Foster, 1961).

Remarks: This is the second known locality for *Phenacomys* remains in the Appalachian Mountains. It is also known from the New Paris #4 local fauna. Its presence in the late Pleistocene of Virginia implies a range reduction of at least 800 miles from that day to this.

Microtus pennsylvanicus (Ord)—Meadow Vole

Material: C.M. 7520-7525. 5 partial skulls, 40 partial palates. (Most of the 281 mandibles listed as *Microtus* sp. are undoubtedly this species as well.)

Distribution: Northern and central North America south in the east to Georgia and South Carolina.

Habitat: Moist grasslands in open or wooded terrain at any altitude.

Remarks: The commonest small mammal in the deposit, and one of the commonest in eastern North America today.

Vernon Bailey (1900, p. 22) states that the presence of a small, lingually-directed loop following the 5th alternating triangle of M^1 is one of the characters of the Ungava subspecies *Microtus p. labradorius*. As this was well developed in many of the Natural Chimneys specimens, it was believed, at first, that this might constitute a direct genetic link between late Pleistocene Virginia and modern Labrador populations of this vole. A study of 26 skulls from Labrador (Nain, Hebron and Windsor) and 26 from south-central Pennsylvania (Adams, Bedford and York counties) in the collections of Carnegie Museum make it apparent that this character is equally well developed in both modern populations. It may be that a statistical study of this character would reveal a geographic pattern, but this character appears to be of little practical value in attempting to establish modern population equivalents for Pleistocene *Microtus pennsylvanicus*.

Microtus chrotorrhinus (Miller)—Rock Vole

Material: C.M. 7507. 1 partial skull, 1 palate.

Distribution: Hudsonian and Canadian life zones of eastern North America.

Habitat: Among rocks, under logs, in forest situations. Prefers cool, damp situations. Rare and local today.

Remarks: The presence of the rock vole may go unrecorded in a deposit of this nature. Mandibles are indistinguishable from those of *M. pennsylvanicus* except for a slightly smaller average adult size. Upper dentitions can not be identified unless the easily lost M^3 is in place, and in its absence, might be mistaken for *Pitymys*. *M. pennsylvanicus* can be identified as such even if M^3 is missing, and often, due to an incipient lingual loop on M^1 , even when both M^2 and M^3 are missing. With modern specimens or exceptionally well-preserved fossil crania, identification is facilitated. But when the specimens are as fragmentary as they are in this collection it is fortunate that two upper dentitions were complete enough to be identified as rock vole. The apparent ratio of 45 *M. pennsylvanicus* to 2 *M. chrotorrhinus* more probably reflects, not the relative abundance of the two species in the area at the time the site was an active owl roost (assuming the two species to be equally vulnerable to predation), but the relative ease with which fragmentary remains of these two species can be identified. Since the habits of *M. chrotorrhinus* probably do serve to protect it from owl predation to a greater extent than the meadow-inhabiting *M. pennsylvanicus*, it may not have been a rare mammal in the vicinity of the Chimneys. This species has not been recorded from Virginia during recent times although it has been trapped within 10 miles of the state line in West Virginia (Handley and Patton, 1947, p. 174). The presence of *M. chrotorrhinus* at the altitude of 1357 ft. in Virginia is indicative of former climatic change. It occurs at altitudes of over 3000 ft. in the central and southern Appalachians today.

Microtus pennsylvanicus or *chrotorrhinus* or both

Material: C.M. 7514, 7515. 169 left, 138 right mandibles or M_1 or both.

Remarks: *Microtus pennsylvanicus* is a larger species, but the range of individual variation in modern specimens often exceeds the specific variation.

Microtus xanthognathus (Leach)—Yellow-cheeked Vole

Material: C.M. 5861, 7526. 24 mandibles, 5 palates, 1 maxilla, isolated molars.

Distribution: Hudsonian life zone, western Canada and Alaska, east to Hudson Bay.

Habitat: A variety of grassland and boreal forest situations, wet or dry; appears to prefer the near presence of water, an extensive burrower.

Remarks: Pleistocene remains known only from this site and from New Paris #4, Pennsylvania (Guilday and Bender, 1960).

cf. *Pitymys pinetorum* (LeConte)—Pine Vole

Material: C.M. 7505. 53 left, 65 right mandibles.

Distribution: Eastern United States west to the Great Plains, north to Wisconsin and southern Maine.

Habitat: A burrower in loose friable soils in field or forest.

Remarks: In the absence of more complete cranial material, the possibility of the presence of the prairie vole, *Pedomys*, can not be completely excluded. The identification of *Pitymys pinetorum*—highly probable since it is one of Virginia's commonest small mammals today—must therefore remain provisional. *Microtus* (or *Pedomys*) cf. *involutus* (Cope) has been reported for Cumberland Cave, Maryland. These specimens I consider to be most probably *P. pinetorum*. *Pitymys pinetorum* based upon adequate cranial material is known from the New Paris #4 local fauna, Pennsylvania.

Ondatra zibethicus (Linnaeus)—Muskrat

Material: C.M. 7506. 5 left, 6 right partial mandibles or M_1 or both, 2 partial palates, isolated molars and post-cranial scraps.

Distribution: Most of North America, north of the lower Austral life zone.

Habitat: A wide variety of aquatic habitats from trout streams to salt marshes.

Remarks: Common in the area today.

Family: Zapodidae

Zapus hudsonicus (Zimmermann)—Meadow Jumping-Mouse

Material: C.M. 7528. 11 left, 13 right mandibles, 5 maxillae.

Distribution: Alaska to Labrador, south in the east to Georgia and Alabama.

Habitat: Grasslands, brushy meadows, swamps.

Remarks: Common in the state at all elevations.

Napaeozapus cf. *insignis* (Miller)—Woodland Jumping-Mouse

Material: C.M. 7529. 4 left, 9 right mandibles, 5 maxillae.

Distribution: Eastern North America from southern Manitoba to southern Labrador, south along the Appalachian Mountains to northern Georgia.

Habitat: Grassy swales, moist, cool forest situations near water.

Remarks: The woodland jumping-mouse is apparently confined to mountain forests in the state today. In the higher ridges it is not an uncommon animal, but it does not occur at the site today. The fragmentary specimens from the Natural Chimneys deposit are larger and more robust than comparable modern Pennsylvania specimens of *N. i. insignis*, and agree in size with the *Napaeozapus* material from the New Paris #4 local fauna. The fragmentary mandible from the Cumberland Cave deposit (Gidley and Gazin, 1938) is apparently larger than modern material as well. Modern populations of this animal seem to show a clinal increase in size towards the north, and the somewhat greater size of these late Pleistocene animals may have been in response to a harsher climate at the time of deposition.

Family: Erethizontidae

Erethizon dorsatum (Erxleben)—Porcupine

Material: C.M. 7543. 3 isolated molars, at least 2 animals.

Distribution: Alaska to Labrador, south along the Appalachian Mountains to Tennessee.

Habitat: Requires woody vegetation, but is extremely adaptable to a variety of habitats from mountain to desert. In eastern United States restricted to the Canadian and Transition zone forests.

Remarks: There appears to be no recent record for the porcupine in the state of Virginia (Handley and Patton, 1947, p. 185). Porcupine remains have been reported from Cavetown and Cumberland caves, Maryland, as well as numerous Pennsylvania cave deposits (Hay, 1923).

Order: LAGOMORPHA

Family: Leporidae

Lepus cf. americanus Erxleben—Snowshoe Hare

Material: C.M. 7556. 1 innominate, 2 ulnae, 1 radius, 1 parietal, 3 frontals, 1 mandible fragment.

Distribution: Hudsonian and Canadian life zones of North America, south to Pennsylvania. South to Tennessee in the higher ridges of the Appalachian Mountains.

Habitat: Coniferous forests, bogs, coniferous-deciduous boreal or mountain woodlands.

Remarks: Confined to the higher mountain ridges of the state, this animal is rare and local today. It was not a member of the Recent fauna at Natural Chimneys. At least three animals are represented in the fragmentary leporid material from the site. Identification was based upon the shape of the postorbital processes of the frontals, the absence of a parietal-interparietal suture, the coronoid process of the mandible, and the shape of the ischium. Remains of snowshoe hares are common in Pleistocene cave deposits in the central Appalachians. They have been reported from Cumberland Cave, Maryland, Frankstown Cave and New Paris #4, Pennsylvania.

Sylvilagus, species ?—Cottontail Rabbit

Material: C.M. 7555. 1 tibia, 1 radius, 1 left mandible, 1 pair of frontals.

Remarks: Probably either *S. floridanus* or *S. transitionalis*, but the specimens were too fragmentary to identify to species.

Leporidae, genus and species

Material: C.M. 7557. Fragments representing a minimum of 13 animals.

Remarks: Undoubtedly a mixture of *Sylvilagus* and *Lepus* as above, but too fragmentary to identify beyond family.

Order: CARNIVORA

Family: Canidae

Canis cf. *lupus* Linnaeus—Wolf

Material: C.M. 7573. 1 right M₂, unerupted; 1 ungual phalange, adult.

Distribution: North America continent from central Mexico to Alaska. Common in Virginia during historic times, now exterminated.

Remarks: The tooth agrees with modern comparative material of *Canis lupus lycaon*, but is not diagnostic enough to rule out the possibility of domestic dog. Wolf is highly probable, however, due to the age of the fauna and absence of any obvious feral or domestic animals from it.

Canidae, species—Fox

Material: C.M. 7588. 1 left deciduous P⁴.

Remarks: The tooth is unworn and broken, only the paracone and metacone are preserved. It was from a fox, most probably *Urocyon* or *Vulpes*.

Vulpes sp. Red ? Fox

Material: C.M. 7482. 1 right P⁴. Fig. 4, A and D.

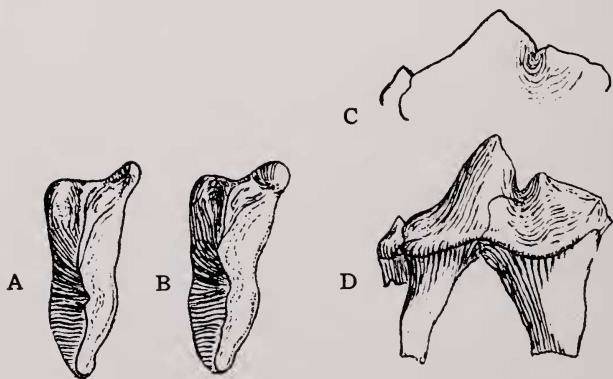


Fig. 4. Right upper fourth premolar, *Vulpes* sp. Natural Chimneys local fauna, A. crown view, D. buccal surface. Right upper fourth premolar, *Vulpes fulva* C.M. mammal 7451. B. crown view. C. buccal surface 2×

Remarks: The tooth is complete and unworn. The roots are open, but in the process of closing. Comparison was made with modern specimens of *Alopex*, *Urocyon* and *Vulpes*. The tooth appears to be from a

fox of the genus *Vulpes*, but it can not be matched with modern specimens of *V. fulva* from eastern North America nor with modern *V. velox* or *V. macrotus*.

The specimen was examined by Charles O. Handley, Jr., U. S. National Museum, who reports: ". . . it is most like *Vulpes fulva*, particularly like specimens from eastern Canada (Labrador and Ontario). Although I would hesitatingly refer it to *Vulpes*, I would not say that it is *Vulpes fulva*. . . . the cusps are more trenchant, the deuterocone is smaller, the whole tooth, and particularly the parastyle, is narrower, and the carnassial notch is more open.

"Although the size of the deuterocone and the width of the tooth are relatively the same in this specimen and in *Vulpes velox* and *Vulpes macrotus*, there are other significant differences. The Natural Chimneys tooth is larger, cusps are more trenchant, carnassial notch is more open, parastyle is slightly narrower, and metastyle is notably longer and lower." (Letter, Jan. 3, 1962).

Two Pleistocene red foxes have been described from eastern North America. *Vulpes latidentatus* Cope, 1899, from Port Kennedy Cave, Pennsylvania is represented by a single M¹ and may be invalid. *Vulpes palmaria* Hay, 1917, from Florida is known only from mandible and skeletal fragments (Ray, 1958, p. 435). The type materials, therefore, can not be compared directly, nor can either, with the Natural Chimneys specimen. Until such time as better fossil material becomes available, this specimen can not be identified to species, although the characters discussed are quite pronounced. Measurements in mm. C.M. 7482. *Vulpes* sp. right P⁴. Length of crown . . . 14.8 mm. Maximum width of crown . . . 5.6 mm.

Family: Ursidae

Ursus cf. *americanus* Pallas—Black Bear

Material: C.M. 7574. 1 right M₃.

Distribution: Formerly most of the continent south of the tree limit. Common in Virginia at all elevations within historic times.

Remarks: Tooth identical to Pennsylvania specimens of *Ursus a. americanus*.

Family: Procyonidae

Procyon cf. *lotor* (Linnaeus)—Raccoon

Material: C.M. 7575. 2 canines, 1 incisor, 1 deciduous P³, 1 upper premolar.

Distribution: Continent-wide south of the boreal forest. Common in Virginia today.

Family: Mustelidae

Martes americana (Turton)—Pine-Marten

Material: C.M. 7613. 1 humerus, 1 ulna.

Distribution: Canadian and Hudsonian life zones of North America, south along the Appalachian crests formerly as far south as Virginia. No modern record of the animal in Virginia.

Habitat: Coniferous forests, preying primarily on hare and squirrel. Semi-arboreal.

Remarks: This appears to be the first record of the pine-marten from Virginia.

Martes pennanti (Erxleben)—Fisher

Material: C.M. 7576. 1 P⁺, 1 M⁺.

Distribution: Formerly throughout most of forested North America south to the Austroriparian life zone.

Habitat: Varied situations in coniferous forest primarily, highly arboreal. A squirrel and rabbit predator.

Remarks: Formerly present in the mountain ridges of the state.

Mustela rixosa (Bangs)—Least Weasel

Material: C.M. 7577. 1 fragmentary left maxilla with dentition, 1 fragmentary left mandible.

Distribution: Northern and central North America south to Ohio, in the Appalachian Mountain region from Pennsylvania south to North Carolina.

Remarks: This animal is so erratic in distribution and choice of habitat that its presence in the deposit has little ecological implication. It is apparently restricted to the mountains of the state today. The specimens, judging from their size, are from female animals.

Mustela cf. *rixosa* or *erminea*—Weasel

Material: C.M. 7578. 4 left, 2 right mandibles, 2 left maxillae.

Remarks: None of the specimens is complete or with full dentitions. Although *M. erminea* is the larger species, the difference in size between the sexes is so great that an isolated mandible of a male *M. rixosa* may equal or exceed that of a female *M. erminea*. (See C.M. 24,918, *M. rixosa allegheniensis* and C.M. 31,206, *M. erminea cicognanii*). The mandible of *M. erminea* is relatively longer and slimmer, and the premolars are relatively larger, but without any knowledge of the sex of the animals represented by the fragmentary specimen from Natural Chimneys, specific identification is uncertain. *M. erminea* is not known from modern Virginia, but at one time it did occur south of its present southern limits, in the Conard Fissure, Arkansas. (Brown, 1908).

Mustela frenata Lichtenstein—Long-tailed Weasel

Material: C.M. 7579. 3 left, 1 right mandible.

Distribution: Mexico, United States, southern Canada.

Habitat: Varied, field or forest.

Remarks: The common weasel in the state today.

Mustela vison Schreber—Mink

Material: C.M. 7580. 2 left, 1 right P⁺, 1 left, 1 right M⁺, 1 C, 1 M₁.

Distribution: Most of North America exclusive of the arid southwest and Mexico. Common in Virginia today.

Habitat: Semi-aquatic.

Mephitis mephitis (Schreber)—Skunk

Material: C.M. 7581. 1 left temporal, premaxillae, partial right mandible.

Distribution: Throughout most of North America south of the tree line. Occurs at the site today.

Family: Felidae

Material: C.M. 7582. 1 penultimate phalange.

Remarks: The characteristic excavation for the reception of the sheathed ungual phalange was present. This was a small animal, possibly a small *Lynx* or a large domestic *Felis*.

Order: ARTIODACTYLA

Family: Tayassuidae

Mylohyus, species ?—Long-nosed Peccary

Material: C.M. 7584, 7586. 2 partial molars, 3 molar fragments, partial right nasal.

Habitat: Associated with a boreal fauna and pollen flora at New Paris #4 local fauna, Pennsylvania.

Remarks: *Mylohyus* remains have been recovered in many Appalachian cave deposits. This peccary occurred in the boreal New Paris #4 local fauna and survived the Wisconsin glaciation to become extinct within the last 10,000-11,000 years (Guilday and Bender, 1960).

Family: Cervidae

Odocoileus cf. *virginianus* (Zimmermann)—Virginia Deer

Material: C.M. 7585. 12 teeth, 2 metapodial fragments, 2 petrous temporals.

Distribution: Most of forested North America, a common Virginia mammal.

Remarks: Both deciduous and permanent teeth are represented.

Cervidae, species ?

Material: C.M. 7586. A partial unerupted incisiform tooth, possibly *Cervus*.

Age of the Natural Chimneys Local Fauna

The fauna is not a temporal unit, but its probable chronological limits seem clear. Introduced species, such as the rat (*Rattus*) or the house mouse (*Mus*), or any domestic mammals are not present. Equally illuminating is the lack of any mammalian species the range of which does not extend as far north as the site today. The spotted skunk (*Spilogale*), and the opossum (*Didelphis*), two mammals common in western Virginia, but suspected of being post-Pleistocene additions to the mammal fauna of the state, are absent. It seems probable then that the fauna is pre-Columbian and, in the light of the complete lack of southern mammals, that it pre-dates the period of post-Pleistocene warming known as the Climatic Optimum. The presence of such ecological incompatibles as the yellow-cheeked vole (*Microtus xanthognathus*) and least shrew (*Cryptotis*) makes it probable that the deposit took thousands of years to accumulate.

Of the 55 species of mammals recorded from the site, four are extinct: the giant beaver (*Castoroides*), the peccary (*Mylohyus*), the squirrel (*Tamiasciurus tenuidens*) and the bat (*Eptesicus grandis*). All these are known to have survived into post-Wisconsin times (Powell, 1948; Guilday and Bender, 1960). All of the remaining species either occur at the site today or have retreated to higher elevations or latitudes with the onset of post-glacial warming. The presence of such boreal forms as the spruce vole (*Phenacomys*), the northern bog lemming (*Synaptomys borealis*), the yellow checked vole (*Microtus xanthognathus*), and the arctic shrew (*Sorex arcticus*) is clear evidence that deposition was taking place at or near the height of a glacial advance. All of these

boreal forms are present in the New Paris #4 local fauna which has a carbon 14 date of $11,300 \pm 1000$ years (Yale Radiation Laboratory No. 727). The collared lemming (*Dicrostonyx hudsonius*), known from the New Paris #4 local fauna, is missing from Natural Chimneys (Guilday and Douth, 1961). This may indicate a later date for the beginning of deposition at the latter site or, more probably, that the collared lemming did not occur as far south as Natural Chimneys during the Pleistocene. Otherwise the faunal correlation between the two sites is firmly established and they are probably very close in time. The Natural Chimneys fauna includes some temperate forms that New Paris #4 does not: the shrew (*Cryptotis parva*), the squirrels (*Sciurus carolinensis* and *Glaucomys volans*), the box turtle (*Terrapene carolina*), and probably the deposit kept accumulating during that period when temperate forms were reoccupying the area.

The deposit appeared to have no stratigraphic sequence so it is not possible to state categorically which of the component species were or were not contemporaneous. The geological evidence, the condition of the bones, the unconsolidated matrix, all seem to be compatible with the faunal evidence and point to an early post-Wisconsin age for the Natural Chimneys local fauna.

Climatic Interpretations

The Natural Chimneys local fauna is so late in time that many of its component species are still living. Environmental inferences concerning the time period involved can be drawn from a study of the modern habitat requirements of such forms. However, the temptation is great to attempt to infer too much.

The geographic ranges and the ecological requirements of organisms vary enormously from species to species, often within the same genus. In certain cases such as a parasitic or an insular form, limiting factors may be clear-cut. But in most cases they are far from clear and so interwoven into the total ecological fabric that they can not be studied individually without losing much of their significance.

One handicap is the necessity of viewing a continuously evolving process from a single point in time. The reason an animal is found in a particular spot today, while it certainly includes the sum of the environmental pressures acting on it at the present time (after all, the animal directly involved is living now, not yesterday) also includes processes and changes that have been in operation, some for millennia.

We also have an incomplete picture of the modern ecological requirements of many of the commonest of mammals. The less that is known of an animal's habitat requirements, the easier it is to be dogmatic about them. The meadow vole, *Microtus pennsylvanicus*, for example, is a grasslands form closely confined to a ground cover of grass or sedge. But this may include such diverse situations as tidal swamps or boreal bogs, extensive meadowland or tiny isolated mountain glades set in dense upland forests both coniferous and deciduous. Although this mouse is limited to grassy areas, such areas may be unrelated and incidental to the regional picture.

The smoky shrew in Virginia today is restricted to cool, moist Transition and Canadian zone forest in mountainous terrain with an understory of ferns and mosses. This is usually the "habitat" that one associates with the animal throughout its range. But Harry R. Roslund (1951), working in central

Pennsylvania, found this shrew, "Common in *Synaptomys* runways in brushy fields of poverty grass. None were taken in hemlock and rhododendron growing in deep humus among sandstone boulders near one of these fields." (Where the author apparently *expected* them to be.)

Other forms such as the big-tailed shrew or the rock vole are severely limited or perhaps highly adapted to areas of rocky talus and are rarely taken elsewhere.

There is a temptation to overstress the ecological implications inherent in the presence of a given species in a Pleistocene fauna, based upon its modern habitat preferences. I can not give much weight to the suggestion that perhaps the ecological requirements of a certain living form were quite different in the past. As the geological age and the taxonomic disparity of faunas increase it becomes more and more hazardous to assume past environmental situations from modern habitat preferences. But when dealing with late Pleistocene forms one is probably safe in assuming that any temporal change in the habitat preferences of a given species has been minimal from that day to this.

The danger lies in the assumption that because a certain species was found in a Pleistocene deposit the habitat was therefore *typical* of that in which the animal occurs today. It may in fact have been marginal and atypical. A muskrat, for example, was recovered from the New Paris #2 sink-hole on a dry hillside a mile from the nearest stream (Guilday and Bender, 1959). When dealing with a fossil occurrence, we can not see the total contemporary range of the form as can be done with modern specimens. We can not even infer too much from the relative numbers of the various forms in a fossil fauna. Sampling error, mode of deposition, methods of recovery, ease of identification, all influence the relative abundance of the component species. This may be quite a different picture from the situation as it actually existed.

The picture improves when an assemblage of species having roughly the same habitat requirements or geographic distribution occur together in a deposit. The chances of an atypical habitat decrease as the size of the recovered fauna increases. It is hard to imagine a considerable segment of a fauna living atypically.

The Natural Chimneys local fauna is rich enough, both in species and in individual animals represented, however, so that its climatic implication seems quite clear.

A summary of the modern climate and environment of the area will serve as background for the climatic deductions to follow.

Modern Climate of Virginia

The present climate of Virginia is temperate and relatively humid; average rainfall is 43.63 inches, varying from 8.8 inches in the fall to 13.22 inches, during the summer months (Hibbard, 1941); average temperature is 59° F., with a winter mean of 40° F. and a summer mean of 77° F.

In a state as rugged as Virginia, however, average figures have little significance. Relief varies from sea-level to the 5720-ft. summit of Mt. Rogers. Temperatures may vary as much as 5° F. per 1000 ft. of ascent during the summer and 2° F. per 1000 ft. during the winter. The lowest temperature recorded at Onley, Virginia at sea-level was -3° F. but temperatures as low

as -44° F. have been recorded in the Virginia and West Virginia mountains at the same latitude but 4000 ft. higher (Brooks, 1943).

During the cooler part of the year Virginia's weather is determined by cyclonic air masses sweeping across the continent from west to east, producing a variable day-to-day succession of weather. Weather patterns in the summer are influenced by warm, moist, tropical air masses. Snowfall is directly correlated with altitude and may be quite heavy in the mountains. Snow never lingers throughout the year. In some sections of the Virginia and West Virginia Appalachians (the Cheat Mountains, W. Va., Brooks, 1943) frosts have been recorded as late as July.

Biotic Zonation in the Virginia and West Virginia Appalachian Mountains

The varied climate and topography of the area today is expressed in the vertical zonation of its plants and animals. Despite the many theoretical objections to the Merriam life zone concept, the practical application of life zones in studies of altitudinal distribution is well established and will be used here with the proviso that these zones merge quite imperceptively and irregularly into one another in the southern Appalachians.

With the exception of the lowland tip of southeastern Virginia, which is in the Austroriparian life zone, most of Virginia east of the Blue Ridge lies in the Carolinian life zone. The floor of the Shenandoah Valley and of deep mountain valleys farther west is also Carolinian. This zone occupies the valley floors up to 1500 ft. and in open country ascends to 2000 ft. Its upper limit may dip as low as 1200 ft., however, in forested ravines (Murray, 1945). All of the mountains, with the exception of a few mountain summits above 4000 ft., lie in the Alleghenian or Transition zone. In the mountains of West Virginia the upper limits of the Alleghenian lie at about 3500 ft. According to Murray, the theoretical upper limits of the Alleghenian life zone should lie between 3000 and 3500 ft. in Virginia but it approaches 4500 ft. on Apple Orchard Peak and Elliott's Knob. Zonation is not a simple function of elevation here but varies altitudinally with slope exposure, air drainage, local precipitation and edaphic factors. "While there is a good deal of Canadian zone territory in the high Allegheny Plateau of West Virginia [700,000 acres before logging, Brooks, 1943, p. 25], and a fair area of it on the great peaks of the Smokies along the North Carolina and Tennessee line there is little or no territory in Virginia which can be called pure Canadian. On White Top and Mt. Rogers, the two highest mountains in Virginia, which reach 5519 and 5720 ft., respectively, we have some small areas which are practically Canadian, and on Middle Mountain in Highland County we have some territory that approaches it." (Murray, 1945, p. 20). After logging, the Canadian zone spruce stands are replaced by Transition zone mixed hardwood-coniferous forest, so the original extent of the state's Canadian zone was undoubtedly somewhat larger than it is today.

The lower limit of the Canadian zone in the Virginia and West Virginia mountains varies considerably. Depending upon local factors it ranges from 3300 ft. (Cranberry Glades, W. Va.) to 4500 ft. (Elliott's Knob, Va.).

Maurice Brooks (letter) is of the opinion that the upper limit of the Canadian zone in the West Virginia mountains would lie between 6000 and 7000 ft. assuming the mountains were that high. Thus we see that in Virginia

today typical Canadian zone conditions either do not exist or are restricted to the highest mountain summits.

Climatic Implications of the Natural Chimneys Local Fauna

The presence of such typical Canadian zone species as the water shrew, the arctic shrew, the snowshoe hare, the pine-marten, the northern flying-squirrel, the northern bog lemming, the spruce vole, the yellow-cheeked vole, the rock vole, the spruce grouse and the gray jay in a cave deposit at 1357 ft. on the floor of the Shenandoah Valley in what is now the Carolinian life zone, indicates a lowering of life zones during late Wisconsin time. There is no reason to assume that biotic zones (similar but not necessarily identical to those of today), were not in existence throughout the late Pleistocene at least. Martin, (1958, p. 383), acting upon this assumption, has constructed a map of the probable life zone situation in eastern North America during full glacial conditions, 18,000 years ago. Although of necessity quite generalized, this model, based primarily upon palynological evidence, agrees quite well with the faunal evidence. The presence of the tundra rodent, *Dicrostonyx* at the New Paris #4 local fauna in southcentral Pennsylvania, and its apparent absence at Natural Chimneys, agrees with Martin's mapping of the tundra and taiga (Hudsonian) zone. Lowland Virginia he places in the boreal forest (Canadian zone), but postulates tundra and taiga conditions on the Appalachian crests.

In order to bring Canadian zone species to the altitude of Natural Chimneys today it would be necessary to depress the lower limits of the Canadian life zone in Virginia by at least 2000 ft. This would place the crests of the Appalachians above timber-line, as Martin's map would indicate. The actual depression may have been even greater. Martin, (1958, p. 382) suggests 4000 ft. This would still be compatible with the Natural Chimneys fauna. In fact, the presence of such distinctly boreal forms as the spruce vole, the northern bog lemming, the yellow-cheeked vole and the arctic shrew is indicative of drastic climatic change beyond the minimum required.

What this implies, of course, is cooler conditions. The presence of the water shrew, smoky shrew, arctic shrew, red-backed vole, and the rock vole would require wetter conditions than occur at the site today. Winters were probably long and severe, summers cooler and very moist. It is conceivable that the broad flat North River valley may have been an extensive boreal bog, affording a vast collecting area for the owls of the Natural Chimneys to draw from. The high incidence of flying-squirrels requires forest cover, but the extremely high proportion of microtines indicates the presence of grasslands as well. The presence of the thirteen-lined ground-squirrel is as yet enigmatic. It is an inhabitant of dry, short-grass prairie in the mid-west, but is known to have occurred at Cumberland Cave, Maryland (Gidley and Gazin, 1938) and during late-Wisconsin times in Pennsylvania (Guilday and Douth, 1961). It is probable that deposition of these bones lasted well into early Recent times but halted before any "Climatic Optimum" range changes could be recorded (The presence of the coachwhip snake, 1 vertebra, and the diamond-backed rattlesnake, 1 vertebra, might be interpreted as such evidence, however).

In summary, the valleys of western Virginia during or shortly following the last glacial advance were probably covered by a coniferous forest inhabited by snowshoe hares, red squirrels, porcupines and pine-marten. Water shrews lived

along the streams that supported muskrat, beaver, and possibly, giant beaver. Long-nosed peccary still roamed the district. A variety of boreal rodents lived in the swampy grasslands. The spruce grouse, the gray jay, the magpie, the northern flying-squirrel, and the red-backed vole lived in these lowland forests. Thirteen-lined ground-squirrels may have occupied the burns resulting from natural forest fires,* sharing these areas with the sharp-tailed grouse. The mountain summits at this time can be envisioned as open barrens, snow-covered most of the year. Outcrops of actively weathering rock clogged the roaring mountain torrents with beds of frost-wedged boulders. The tree line occurred somewhere on the mountain slopes, ascending ever higher as the ice receded. As the Canadian forest ascended the mountains, it was replaced in the warming lowlands by the temperate forest trees of today. Post-glacial warming has forced the Canadian zone spruce up to the highest mountain summits in Virginia where it still clings, a relict of former days.

Summary

See map, Fig. 5, page 119.

A late Pleistocene and early Recent fauna of at least 14 species of invertebrates and 120 species of vertebrates was recovered from caves at the Natural Chimneys, Mt. Solon, Augusta County, Virginia. These fragmentary bones and teeth constitute the Natural Chimneys local fauna. Many of the species are found only in the Canadian and Hudsonian life zones today, some survive only in Canada, four are extinct.

They are indicative of a boreal climate on the floor of the Shenandoah Valley of Virginia during late glacial times ca. 10,000-15,000 years ago. The lower limit of the Canadian life zone appears to have been depressed at least 2000 ft. to include all of the western valley floors of the state.

* I am indebted to P. S. Martin for this suggestion.

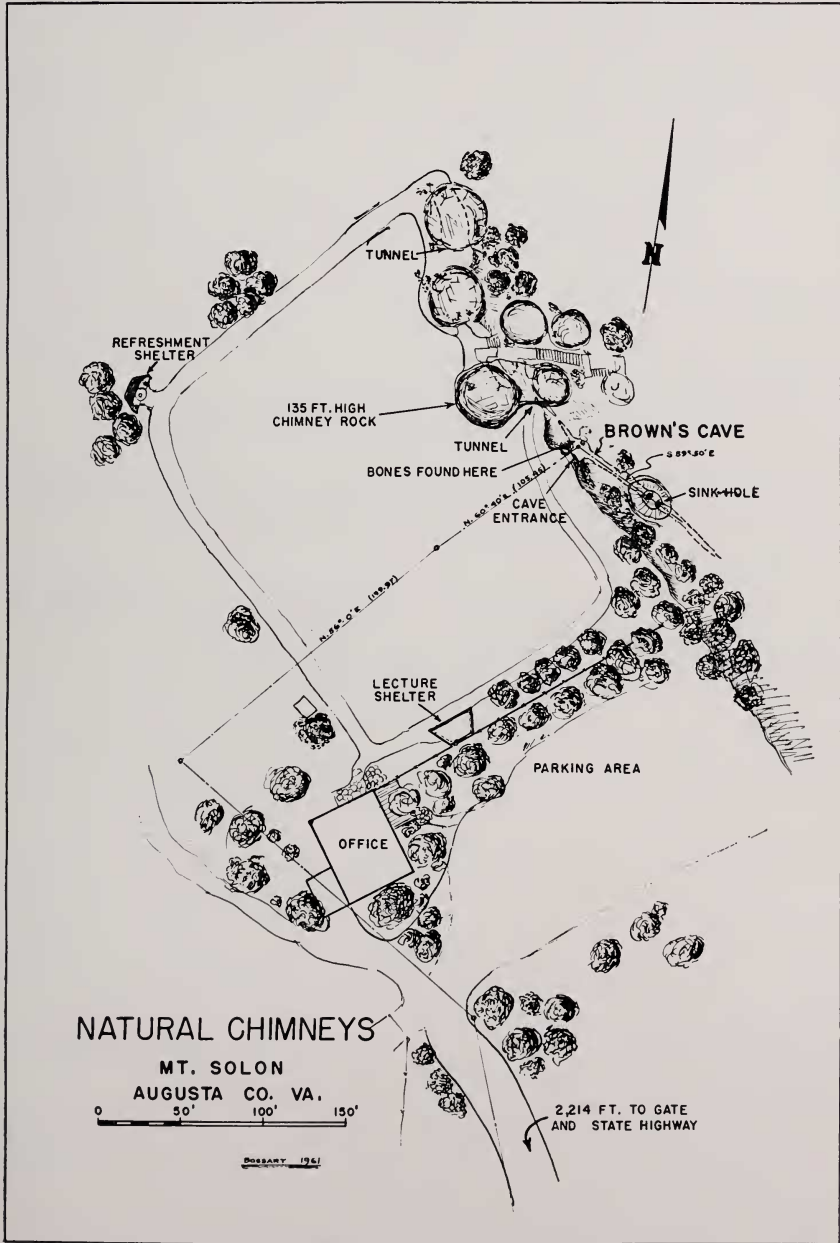


Fig. 5. Map of Natural Chimneys, Mount Solon, Virginia

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